
NUCLEAR ENERGY RESEARCH INITIATIVE

Innovative Low-Cost Approaches to Automating QA/QC of Fuel Particle Production Using On-line Nondestructive Methods for Higher Reliability

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Sub-millimeter TRISO fuel particles having multiple layers of pyrocarbon and silicon carbide are used in several current research systems and proposed advanced nuclear reactor fuel designs. The performance of these micro-spheres is a key component in system containment and depends particularly heavily on the properties and performance of the silicon carbide layer. Present day quality assurance and quality control (QA/QC) methods, done manually and in many cases destructively, are unable to test economically the large numbers of fuel particles that are required in fuel fabrication for advanced reactor concepts.

The project is designed to provide the United States with key enabling advanced inspection technologies for application to "fuel particles" (TRISO particles). These technologies are required for the economical production of reactor fuels being proposed for several Nuclear Power 2010 and Generation IV designs. The project will explore, adapt, develop, and demonstrate innovative nondestructive test methods that will provide in-line measurements for qualification of multilayered (TRISO) nuclear fuel particles and provide improved QA/QC.

The project will focus on nondestructive technologies that can be automated for production speeds, particularly those with potential for implementation as in-line measurements. Supporting studies will be performed on techniques with potential for either on-process implementation (where average properties of a batch of particles can be characterized) and those that can be used to give enhanced off-line measurements. The primary task for both the in-line and off-line tests will be to provide standard signatures for both acceptable particles and the most problematic types of defects. The data from the signatures will be used as the basis for establishing and demonstrating a multiple attribute "Quality Index,"

which can be used to integrate data and can be applied to grade both individual and batches of particles.

The primary thrust of the project will be in-line measurements, and this will focus on the assessment of the potential of electrical property measurements, which have potential for noncontact, rapid, volumetric property determination. It is proposed that these will be combined with advanced optical measurements to give shape and size assessment. It is intended that the data from these two methodologies will be integrated to give a Quality Index for both individual particles and batches of particles.

Supporting studies and particle characterization will be performed using high resolution computed tomography, acoustic microscopy, and resonance ultrasonic spectroscopy. Data from these studies will be used to assess the performance of the integrated electrical and optical measurements. If required to provide additional in-line characterization, an additional technology, from among those identified above, will be developed to support the optical and electrical measurements. The potential for the use of low-frequency ultrasonics as an on-process tool for monitoring batch properties will be evaluated.

The benefits from the successful completion of the project follow:

- Demonstration of the feasibility of using electrical measurements (eddy current/dielectric constant), integrated with advanced optical testing, for on-line TRISO QA/QC
- Development and demonstration of a Quality Index to measure both individual and batch conformity
- Sets of well-characterized surrogate particles for use in QA/QC technology evaluations

- An assessment of the capabilities of using acoustic microscopy, resonant ultrasound spectroscopy (RUS) and high resolution computed tomography for both in-line and/or advanced off-line NDE/QA-QC measurements on TRISO fuel particles
- Provision of proof-of-principle data for the use of transmission and diffuse field ultrasound for on-process monitoring and to provide improved quality control
- Availability of a family of QA/QC tools, which have been evaluated on surrogate fuel particles and are ready to be transitioned for use on a pilot plant scale for a TRISO fuel, or similar nuclear fuel fabrication line